

FORM PTO-1350 (Modified) (REV. 11-2000)		U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	
<b>TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371</b>		ATTORNEY'S DOCKET NUMBER <b>22188/06465</b>	
INTERNATIONAL APPLICATION NO. <b>PCT/US00/17414</b>		INTERNATIONAL FILING DATE <b>23 June 2000</b>	
		U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR) <b>10/069671</b>	
		PRIORITY DATE CLAIMED <b>25 August 1999</b>	
TITLE OF INVENTION <b>APPARATUS AND METHOD FOR WELDING DUPLEX STAINLESS STEEL</b>			
APPLICANT(S) FOR DO/EO/US <b>Ames, et al.</b>			
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:			
<ol style="list-style-type: none"> <li>1. <input checked="" type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li>2. <input type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li>3. <input type="checkbox"/> This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (24) indicated below.</li> <li>4. <input type="checkbox"/> The US has been elected by the expiration of 19 months from the priority date (Article 31).</li> <li>5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371 (e) (2))           <ol style="list-style-type: none"> <li>a. <input type="checkbox"/> is attached hereto (required only if not communicated by the International Bureau).</li> <li>b. <input type="checkbox"/> has been communicated by the International Bureau.</li> <li>c. <input checked="" type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US).</li> </ol> </li> <li>6. <input type="checkbox"/> An English language translation of the International Application as filed (35 U.S.C. 371(e)(2)).           <ol style="list-style-type: none"> <li>a. <input type="checkbox"/> is attached hereto.</li> <li>b. <input type="checkbox"/> has been previously submitted under 35 U.S.C. 154(d)(4).</li> </ol> </li> <li>7. <input type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))           <ol style="list-style-type: none"> <li>a. <input type="checkbox"/> are attached hereto (required only if not communicated by the International Bureau).</li> <li>b. <input type="checkbox"/> have been communicated by the International Bureau.</li> <li>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</li> <li>d. <input type="checkbox"/> have not been made and will not be made.</li> </ol> </li> <li>8. <input type="checkbox"/> An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).</li> <li>9. <input checked="" type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).</li> <li>10. <input type="checkbox"/> An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).</li> <li>11. <input type="checkbox"/> A copy of the International Preliminary Examination Report (PCT/IPEA/409).</li> <li>12. <input checked="" type="checkbox"/> A copy of the International Search Report (PCT/ISA/210).</li> </ol>			
<b>Items 13 to 20 below concern document(s) or information included:</b>			
<ol style="list-style-type: none"> <li>13. <input type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.</li> <li>14. <input checked="" type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.</li> <li>15. <input type="checkbox"/> A <b>FIRST</b> preliminary amendment.</li> <li>16. <input type="checkbox"/> A <b>SECOND</b> or <b>SUBSEQUENT</b> preliminary amendment.</li> <li>17. <input type="checkbox"/> A substitute specification.</li> <li>18. <input type="checkbox"/> A change of power of attorney and/or address letter.</li> <li>19. <input type="checkbox"/> A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.</li> <li>20. <input type="checkbox"/> A second copy of the published international application under 35 U.S.C. 154(d)(4).</li> <li>21. <input type="checkbox"/> A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).</li> <li>22. <input checked="" type="checkbox"/> Certificate of Mailing by Express Mail</li> <li>23. <input checked="" type="checkbox"/> Other items or information:</li> </ol>			
<p style="text-align: center;">Postcard</p>			

U.S. APPLICATION NO. (IF KNOWN) <b>37 CFR 1.07069671</b>	INTERNATIONAL APPLICATION NO. <b>PCT/US00/17414</b>	ATTORNEY'S DOCKET NUMBER <b>22188/06465</b>
--	---	---

24. The following fees are submitted: <b>BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :</b> <input type="checkbox"/> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO ..... <b>\$1040.00</b> <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO ..... <b>\$890.00</b> <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... <b>\$740.00</b> <input checked="" type="checkbox"/> International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) ..... <b>\$710.00</b> <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfy provisions of PCT Article 33(1)-(4) ..... <b>\$100.00</b>	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th colspan="2" style="text-align: left;">CALCULATIONS</th> <th style="text-align: left;">PTO USE ONLY</th> </tr> <tr> <td colspan="2">ENTER APPROPRIATE BASIC FEE AMOUNT =</td> <td>\$710.00</td> </tr> <tr> <td colspan="2">Surcharge of \$130.00 for furnishing the oath or declaration later than months from the earliest claimed priority date (37 CFR 1.492 (e)). <input type="checkbox"/> 20 <input type="checkbox"/> 30</td> <td>\$0.00</td> </tr> <tr> <td>CLAIMS</td> <td>NUMBER FILED</td> <td>NUMBER EXTRA</td> </tr> <tr> <td>Total claims</td> <td>43 - 20 =</td> <td>23</td> </tr> <tr> <td>Independent claims</td> <td>5 - 3 =</td> <td>2</td> </tr> <tr> <td colspan="2">Multiple Dependent Claims (check if applicable).</td> <td><input type="checkbox"/></td> </tr> <tr> <td colspan="2"><b>TOTAL OF ABOVE CALCULATIONS =</b></td> <td><b>\$1,292.00</b></td> </tr> <tr> <td colspan="2"><input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2.</td> <td>\$0.00</td> </tr> <tr> <td colspan="2"><b>SUBTOTAL =</b></td> <td><b>\$1,292.00</b></td> </tr> <tr> <td colspan="2">Processing fee of \$130.00 for furnishing the English translation later than months from the earliest claimed priority date (37 CFR 1.492 (f)). <input type="checkbox"/> 20 <input type="checkbox"/> 30</td> <td>\$0.00</td> </tr> <tr> <td colspan="2"><b>TOTAL NATIONAL FEE =</b></td> <td><b>\$1,292.00</b></td> </tr> <tr> <td colspan="2">Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) (check if applicable).</td> <td><input checked="" type="checkbox"/> \$40.00</td> </tr> <tr> <td colspan="2"><b>TOTAL FEES ENCLOSED =</b></td> <td><b>\$1,332.00</b></td> </tr> <tr> <td colspan="2"></td> <td>Amount to be: refunded \$ charged \$</td> </tr> </table>	CALCULATIONS		PTO USE ONLY	ENTER APPROPRIATE BASIC FEE AMOUNT =		\$710.00	Surcharge of \$130.00 for furnishing the oath or declaration later than months from the earliest claimed priority date (37 CFR 1.492 (e)). <input type="checkbox"/> 20 <input type="checkbox"/> 30		\$0.00	CLAIMS	NUMBER FILED	NUMBER EXTRA	Total claims	43 - 20 =	23	Independent claims	5 - 3 =	2	Multiple Dependent Claims (check if applicable).		<input type="checkbox"/>	<b>TOTAL OF ABOVE CALCULATIONS =</b>		<b>\$1,292.00</b>	<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2.		\$0.00	<b>SUBTOTAL =</b>		<b>\$1,292.00</b>	Processing fee of \$130.00 for furnishing the English translation later than months from the earliest claimed priority date (37 CFR 1.492 (f)). <input type="checkbox"/> 20 <input type="checkbox"/> 30		\$0.00	<b>TOTAL NATIONAL FEE =</b>		<b>\$1,292.00</b>	Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) (check if applicable).		<input checked="" type="checkbox"/> \$40.00	<b>TOTAL FEES ENCLOSED =</b>		<b>\$1,332.00</b>			Amount to be: refunded \$ charged \$
CALCULATIONS		PTO USE ONLY																																												
ENTER APPROPRIATE BASIC FEE AMOUNT =		\$710.00																																												
Surcharge of \$130.00 for furnishing the oath or declaration later than months from the earliest claimed priority date (37 CFR 1.492 (e)). <input type="checkbox"/> 20 <input type="checkbox"/> 30		\$0.00																																												
CLAIMS	NUMBER FILED	NUMBER EXTRA																																												
Total claims	43 - 20 =	23																																												
Independent claims	5 - 3 =	2																																												
Multiple Dependent Claims (check if applicable).		<input type="checkbox"/>																																												
<b>TOTAL OF ABOVE CALCULATIONS =</b>		<b>\$1,292.00</b>																																												
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2.		\$0.00																																												
<b>SUBTOTAL =</b>		<b>\$1,292.00</b>																																												
Processing fee of \$130.00 for furnishing the English translation later than months from the earliest claimed priority date (37 CFR 1.492 (f)). <input type="checkbox"/> 20 <input type="checkbox"/> 30		\$0.00																																												
<b>TOTAL NATIONAL FEE =</b>		<b>\$1,292.00</b>																																												
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) (check if applicable).		<input checked="" type="checkbox"/> \$40.00																																												
<b>TOTAL FEES ENCLOSED =</b>		<b>\$1,332.00</b>																																												
		Amount to be: refunded \$ charged \$																																												

a. <input checked="" type="checkbox"/> A check in the amount of <b>\$1,332.00</b> to cover the above fees is enclosed. b. <input type="checkbox"/> Please charge my Deposit Account No. _____ in the amount of _____ to cover the above fees. A duplicate copy of this sheet is enclosed. c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <b>03-0172</b> . A duplicate copy of this sheet is enclosed. d. <input type="checkbox"/> Fees are to be charged to a credit card. <b>WARNING:</b> Information on this form may become public. <b>Credit card information should not be included on this form.</b> Provide credit card information and authorization on PTO-2038.	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> </div> <div style="border: 1px solid black; padding: 5px;"> <b>SIGNATURE</b>  <b>John E. Miller</b>  <b>NAME</b>  <b>26,206</b>  <b>REGISTRATION NUMBER</b>  <b>2/22/02</b>  <b>DATE</b> </div>
--	---

**NOTE:** Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

**SEND ALL CORRESPONDENCE TO:**  
**John E. Miller, Esq.**  
**CALFEE, HALTER & GRISWOLD LLP**  
**1400 McDonald Investment Center**  
**800 Superior Avenue**  
**Cleveland, Ohio 44114**

**"EXPRESS MAIL"** Mailing Label No.: EL085170419W  
 Date of Deposit: 2/22/02  
 I hereby certify that this power or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the

**APPARATUS AND METHOD FOR  
WELDING DUPLEX STAINLESS STEEL**

**Cross-Reference to Related Application**

The present application is based on United States Provisional Application SN 60/150,738, filed August 25, 1999, the benefit of which is hereby claimed. The disclosure of this application is also incorporated herein by reference.

**Technical Field of the Invention**

The present invention relates to welding processes for duplex stainless steels. More particularly, the invention relates to the use of a flux, and optionally a weld ring, to weld duplex stainless steel using, for example, an orbital welder.

**Background of the Invention**

Duplex stainless steel is becoming more widely used in applications that require high strength and corrosion resistance. A typical example is deep sea applications in the oil and gas industry. Particularly for high pressure operations, thick walled or heavy duplex tubing may be required. By "thick walled" or "heavy" tubing, which are used interchangeably herein, is meant duplex tubing greater than 2 mm wall thickness. For most applications, duplex tubing is welded either to additional sections of duplex tubing or to fittings, valves and so forth all of which may be made of duplex steel.

Duplex steel is characterized by a phase balance between austenite and ferrite in the steel crystalline structure. In general, duplex stainless steels contain about 30 to 70 vol.% ferrite, more typically about 35 to 60 vol.% ferrite, even more typically about 40 to 45 vol.% ferrite, with the balance being

austenite. Maintaining the austenite/ferrite phase balance is very important in that the austenitic phase contributes to the pitting corrosion resistance of the steel while the ferrite phase contributes to greater strength and resistance to chloride stress corrosion cracking.

Welding of duplex steels presents special challenges, since a proper phase balance and nitrogen content must be maintained in the weld metal as well as in the surrounding heat affect zone (HAZ). This is because welding subjects the material forming the weld bead to additional high heat, melting, cooling and solidification. Many factors associated with the welding process can affect the phase balance in the weld metal. These factors include the welding temperature, cooling rate, type of purge gas used during the welding operation and the chemistry of the weld pool. If the final weld solidifies with too much austenite, the strength of the weld can be compromised. If the weld solidifies with too much ferrite, the weld and HAZ may exhibit lower corrosion resistance.

Welding of steel tubing is done both manually and by machine. In both operations, sagging or drop through of the weld pool should be avoided so that the weld bead is uniform in profile along its entire length. In addition, the weld bead should not be too wide in profile, since a weld bead which solidifies too slowly may exhibit improper metallurgy in terms of both chemistry and phase structure. Incomplete penetration through the tube wall should also be avoided.

Machine welding of steel tubing is typically done commercially using orbital welding equipment in which heat for welding is derived from an electric arc generated by a pulsed electric current. The arc emanates from an electrode

positioned outside the tubing adjacent the weld junction to be formed, with the electrode being moved by the machine orbitally (circumferentially) around the tubing along its entire circumference. Preferably, orbital welding is accomplished in a single pass (plus an additional 30° to 120° in some instances to complete the weld smoothly), since this approach minimizes problems occurring when a previously formed weld bead is remelted.

Thick walled duplex tubing is particularly difficult to weld, since the factors causing poor weld profile and improper phase balance magnify as tube wall thickness increases. Therefore, it has not been possible to achieve acceptable weld quality when machine welding duplex steel tubing of heavy wall thickness. Although manual welding can achieve acceptable weld quality, a highly skilled welder is required. Moreover, multiple weld passes are also required, which only exacerbates the complexity and expense of the welding process.

It is, therefore, an object of the present invention to provide welding apparatus and methods that significantly improve the weldability of duplex stainless steel by producing acceptable weld profiles and weld beads exhibiting a proper duplex phase balance and nitrogen retention.

It is a further object of the present invention to provide a welding process and apparatus that facilitate machine based welding, especially single pass orbital welding, of duplex stainless steel tubing, especially thick walled duplex stainless steel tubing.

#### **Summary of the Invention**

In accordance with the present invention, it has been found that duplex steel tubing and other parts can be easily joined by machine based arc welding provided that a high-refractory flux is present in the HAZ (heat affected zone) and further that the electric arc generated for welding is non-pulsed. In particular, it has been found that the weld bead produced when welding duplex steel parts together will reliably and consistently achieve the desired duplex phase balance, nitrogen levels and bead profile if a high-refractory flux is present in the HAZ, provided that the arc supplying the weld heat is generated by a non-pulsed electric current.

Accordingly, the present invention in its broader aspects provides a new process for welding duplex steel parts in which formation of a weld bead having a duplex stainless steel phase structure is facilitated by carrying out the welding operation in the presence of a high refractory flux. In addition, the present invention also provides a new process for arc welding duplex steel tubing in which a weld bead having a duplex stainless steel phase structure, a desired nitrogen level and a uniform profile is achieved by carrying out welding in the presence of a high refractory flux with the heat for welding being derived from an arc generated by a non-pulsed electric current.

#### **Brief Description of the Drawing**

The invention may take physical form in certain parts and arrangements of parts, preferred embodiments and a method of which will be described in detail in this specification and illustrated in the accompanying drawing which form a part hereof, and wherein is illustrated an apparatus for welding duplex steel thick walled tubing.

### **Detailed Description of the Preferred Embodiments**

The present invention can be used for welding a wide variety of parts together that are made of duplex stainless steel, especially but not necessarily thick walled or heavy duplex tubing and tube ends. In particular, the present invention is directed to welding together two or more parts, at least one of which is formed from a duplex steel, and further in which the weld bead formed by the welding operation also has a duplex structure.

As mentioned above, duplex stainless steels contain about 30 to 70 vol.% ferrite, more typically about 35 to 60 vol.% ferrite, even more typically about 40 to 45 vol.% ferrite, with the balance being austenite. The weld beads produced by the inventive process also have a duplex stainless steel phase structure, meaning they also contain these amounts of austenite and ferrite, since this balance of phases is needed to achieve the high strength and corrosion resistance characteristic of duplex steels.

In accordance with the present invention, it has been found that a weld bead having the above desired phase balance and nitrogen levels, as well as an appropriate profile, can be formed when welding duplex steel, provided that a high-refractory flux is present in the HAZ and the electric arc used for supplying the welding heat is non-pulsed.

Weld fluxes are well known products of commerce extensively used in the welding industry. Basically, they serve as surface active agents causing the molten weld pool to flow in a desired manner, i.e. to amalgamate or consolidate along the surface being heated into a compact mass. The effectiveness of a weld flux in promoting consolidation of a weld pool is measured in terms of

SCANNED, # \_\_\_\_\_

penetration characteristic of the weld, which is the ratio of the weld depth to its width at its widest point. In accordance with the present invention, welds can be produced with penetration coefficients of 0.33 or greater, preferably 0.5 or greater, more preferably 1.0 or greater.

Many different materials have been used for weld fluxes. Most typical are chlorides and fluorides such as magnesium chloride, ferric chloride, tin chloride and various sulfur containing compounds. In accordance with the present invention, we have discovered that these typical weld fluxes are ineffective in achieving a duplex weld bead with the desired phase balance and profile. In particular, we have determined that such fluxes contaminate the weld pool with extraneous materials such as chloride, fluoride and/or sulfur atoms, thereby adversely affecting the phase balance and chemistry of the weld bead ultimately produced. In the present invention, therefore, a different type of weld flux is used, referred to herein as "high refractory" fluxes.

A high refractory flux in accordance with the present invention is any material which will impart surface active properties to the weld pool which it contacts in the manner of conventional welding fluxes, but which also does not contaminate the molten weld pool with extraneous atoms as a result of the welding operation. Examples of materials which are useful for this purpose are the refractory oxides such as silica, titania, magnesia, chromia,  $\text{TiO}$ , and the like. An especially preferred weld flux is composed of a mixture of  $\text{Cr}_2\text{O}_3$ ,  $\text{SiO}_2$  and an oxide of titanium, particularly a mixture of about 30 to 70 wt.% of a titanium oxide ( $\text{TiO}$  and/or  $\text{TiO}_2$ ), 20 to 76 wt.%  $\text{Cr}_2\text{O}_3$  and 5 to 27 wt.%  $\text{SiO}_2$ , as described in US Patent No. 5,804,792, the disclosure of which is incorporated



herein by reference. A flux comprising about 50% oxide of titanium, about 40%  $\text{Cr}_2\text{O}_3$  and about 10%  $\text{SiO}_2$  is especially preferred. Generally, such fluxes are supplied in admixture with a liquid carrier such as water or an organic material such as acetone or methyl ethyl ketone. An exemplary flux of this type is LFX-SS7 flux available from Liburdi Dimetrics Company of Dundas, Ontario, Canada.

These fluxes are used in accordance with the present invention in the same way as conventional welding fluxes. Thus they may be applied in the same amounts, to the same locations, and at the same time, as conventional fluxes. Where a weld ring is used, in accordance with a preferred embodiment of the invention as describe below, the weld flux may be applied to the weld ring only, before or after the weld ring is joined to the tubes being welded, or it may be applied the tubes themselves, or to both the weld ring and the tubes.

Once the weld flux is applied, the duplex parts to be joined are welded in a conventional manner. Where welding is accomplished by arc welding, it is preferable in accordance with the present invention to use non-pulsed welding — i.e., arc welding in which the electric current generating the arc is non-pulsed, preferably continuous. In a typical orbital welding operation, pulsed electrode currents are used because they are easier to regulate and to use to control heat at the weld zone. However, we have found that weld beads produced with pulsed arcs are unacceptably porous and non-uniform if a high refractory weld flux, as described above, is present during welding. Although not wishing to be bound to any theory, we believe unacceptable welds are produced when pulsed arcs are used together with high refractory fluxes

because of excessive turbulence created in the weld pool. Non-pulsed arcs smooth out the rate heat is applied and thereby reduce or eliminate excessive heat generation and attendant turbulence during peaks in the electrical cycle.

In standard arc welding, current pulsing occurs at 2 to 20 Hertz, typically, with amplitudes generally varying between 100% and 30% of peak. "Non-pulsed" as used herein means that the period of the pulse is lengthened and/or the variation between maximum and minimum amplitude is reduced so that violent turbulence and its attendant adverse effect on weld quality is substantially eliminated. Preferably, direct (continuous) current is used, as this completely eliminates the adverse effects of pulsing. Using non-pulsed arcs in accordance with the present invention has also been found to reduce the total amount of electrical power required for welding.

A particular advantage of the present invention is that high quality welds having the desired austenite/ferrite balance, nitrogen levels and bead profile can be produced in a single electrode pass, even if the wall thickness of the tubing being welded exceeds 2 mm. Orbital welding of duplex steel tubing using conventional technology is difficult at best and impossible, as a practical matter, when the wall thickness of the tubing exceeds 2 mm. Welding duplex tubing of this thickness manually is possible, but very difficult, and in any event multiple passes are required. In accordance with the present invention, however, tubing of this thickness can be readily welded together with conventional orbital welders even when the welders are operated in a single pass mode. In this connection, it should be understood that single pass operation as contemplated herein includes extending the pass of the electrode by an additional 30, 45, 90,

120 or even 180 degrees beyond a single complete revolution in order to smooth out completion of the weld. Good results, however, can still be accomplished with a single pass of 360 degrees.

In accordance with another embodiment of the invention, the weld pool is formed using additional alloy elements supplied by a weld filler material. Using weld fillers to supply additional alloying elements to a weld is a common welding practice. Since the metallurgy of a weld can often be different from that of the underlying base metal, additional alloying elements supplied by a weld filler can be used to alter the chemistry of the weld so as to achieve a more desirable chemistry and metallurgy. This effect can be used in welding duplex steels in accordance with the present invention to tailor the austenite/ferrite balance of the weld bead produced closer to a desired value.

In this connection, welds produced from duplex steels tend to have a lower proportion of austenite than the base metals from which they are melted. Therefore, this effect can be offset, and the desired phase balance maintained, at least approximately, by using a weld filler whose alloying elements tend to promote austenite formation. Nickel helps stabilize or enhance austenite formation during solidification, while chromium fosters ferrite formation. Therefore, using a weld filler that is over alloyed with nickel compared to the base metal being welded is a desirable approach in accordance with the present invention. For example, a weld filler made of 25.10.4.L filler material available from Sandvik Corporation can be used advantageously for welding 2507 duplex stainless steel also available from Sandvik.

Weld filler materials in accordance with this aspect of the invention can be supplied in any conventional manner. For example, they can be supplied in the form of wire, for use in manual as well as machine based welding, or they can be supplied in the form of weld rings for insertion between and attachment to the ends of the tubes being welded. Preferably, the weld filler is supplied in the form of a weld ring T-shaped in profile since this allows the tube ends to be physically secured together before welding. Also, if desired, the high refractory flux to be used in the inventive process can be applied to the weld ring separately from the tube ends to be welded before or after the weld ring is attached to the tubing to be welded. Indeed, the ingredients of the high refractory flux can even be incorporated into the weld ring when it is made, if desired.

Orbital welding can be carried out using an open system, that is apparatus in which the gap between the weld electrode and tubing being welded is open to the atmosphere, or a closed system in which this gap is enclosed. In either case, it is customary to flush the gap with a shielding gas for substantially eliminating oxygen from the vicinity of the weld and for carrying off any gases produced by the welding operation.

A variety of different gases have been used as shielding gases in conventional welding processes. Examples are the noble gases, especially argon, nitrogen and other gases. Nitrogen when used as a shielding gas in concentrations as low as 2% is known to enhance austenite formation in many different steels and so is a preferred choice in many applications. Hydrogen has also been used. In accordance with the present invention, however, it has

been found that nitrogen and hydrogen, in concentrations as low as 2%, cause an "explosion" of the weld pool created in the inventive process when a high refractory flux is present. Accordingly, hydrogen, nitrogen and all other gases having a similar effect are preferably avoided in carrying out the present invention. Thus, the shield gas used in this embodiment of the invention can include inert gases such as the noble gases (helium, argon, neon and xenon) as well as any other gas which does not react with the weld pool or the high refractory flux under the conditions encountered during welding.

The present invention will now be exemplified by a particular embodiment which is illustrated in the drawing:

Apparatus 10 for welding together tube ends 28 and 30 of duplex steel tubes 33 and 39 includes in a preferred embodiment an orbital welder device 12, a weld ring 14 and a flux material 16. The orbital welder may be, for example, an orbital welding system and power supply such as model M-100 available from Swagelok Company of Solon, Ohio. Other welding techniques well known to those of ordinary skill in the art can be used however, including but not limited to manual welding systems. In the exemplary embodiment, duplex steel tubes 33 and 39 are formed from SAF 2507 steel available from Sandvik Corporation of Sandviken, Sweden.

A weld filler material, such as for example, Alloy 25.10.4.L also available from Sandvik, is formed into a consumable insert or weld ring 14. Weld ring 14 is completely consumed in the weld puddle during the welding operation. A significant characteristic of Alloy 25.10.4.L is that it is over alloyed with nickel compared to the base metal being welded. The additional

nickel helps stabilize or enhance the austenite formation in the weld during solidification.

Alloy 25.10.4.L is commercially available in wire form from Sandvik Corporation. In accordance with one aspect of the invention, the filler wire is formed into a weld ring having a radial inner ring 20 and a circumferential axially extending ring 22 integral therewith. The weld ring 14 is appropriately dimensioned to slip onto each end of the tube ends being welded together. The weld ring 14 shape also aids in joint alignment which is particularly useful with orbital welding apparatus. Weld ring 14 can be formed by any convenient process such as by sintering, stamping and so forth.

Flux 16 is LFX-SS7 flux available from Liburdi Dimetrics. Other fluxes may be used as mentioned above. Preferably, flux 16 is applied to an outer surface 14a of the weld ring and on adjacent tube surfaces. Surface application facilitates the penetration enhancing characteristic of the flux. The flux 16 is typically available in powder form, but in this case is mixed with a liquid carrier to form a paste that is manually brushed on weld ring 14. The liquid carrier evaporates and the flux remains loosely adhered to the weld ring 14. The flux is preferably entirely consumed during the welding operation, however, flux residue can be easily cleaned from the final weldment as required. Preferably, the flux is kept near the outer surface of the weld ring 14, as shown in the figure.

Flux 16 improves heat penetration in the weld, thus reducing the weld width which reduces the potential for sagging and other weld profile problems that commonly occur during attempts to do a single pass welding operation with

thick walled components. By more efficiently directing the heat inward to reduce weld pool spread, the welding operation uses lower currents for full penetration. Reduced current allows for welding with smaller lower power weld heads and power supplies and also further aids in maintaining austenite in the weld.

In operation, the tube ends 28 and 30 of tube sections 33 and 39 are abutted together with weld ring 14 therebetween. Orbital welder 12 is used to perform a single pass welding operation using argon gas as the shield gas. For a typical duplex tube having a wall thickness of 0.095 inch and a tube diameter of 0.5 inch, acceptable welds are achieved using a welding current/voltage of 50 amps and 9 Volts at an electrode travel speed of 2.1 inches per minute. The weld bead produced in this manner has an austenite/ferrite ratio of 58/42 and a uniform profile along its entire width with a penetration characteristic (ratio of weld depth to maximum weld width) of 0.5.

The invention has been described with reference to the preferred embodiment. Obviously, modifications and alterations will occur to others upon a reading and understanding of this specification. It is intended to include all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

**CLAIMS**

We claim:

1. A process for welding duplex stainless steel parts comprising carrying out welding in the presence of a high refractory flux thereby forming a weld bead having a duplex stainless steel phase structure.
2. The process of claim 1, wherein the refractory flux comprises at least one of silica, titania, magnesia, chromia and TiO.
3. The process of claim 2, wherein the refractory flux comprises a mixture of  $\text{Cr}_2\text{O}_3$ ,  $\text{SiO}_2$  and an oxide of titanium.
4. The process of claim 1, wherein welding is accomplished by arc welding using a non-pulsed electrical arc.
5. A process comprising arc welding duplex stainless steel tubing using heat generated by a non-pulsed electric current in the presence of a refractory flux to form a weld bead with a duplex stainless steel phase structure and a uniform profile.
6. The process of claim 5, wherein the weld bead has a penetration characteristic of 0.33 or greater.
7. The process of claim 6, wherein the arc welding process is arc welding carried out in an enclosed system so as to shield the gap between the electrode producing the arc and the tubing being welded from atmospheric oxygen.
8. The process of claim 7, wherein the gap is flushed with a shield gas non-reactive with the weld pool and high refractory flux.
9. The process of claim 8, wherein the shield gas is inert gas helium, argon, neon xenon or mixtures thereof.



10. The process of claim 9, wherein additional alloying elements are supplied to the weld pool formed during welding by a weld filler having a higher nickel content than the metal forming the duplex steel to be welded.

11. The process of claim 8, wherein additional alloying elements are supplied to the weld pool formed during welding by a weld filler having a higher nickel content than the metal forming the duplex steel to be welded.

12. The process of claim 11, wherein the refractory flux comprises at least one of silica, titania, magnesia, chromia and TiO.

13. The process of claim 12, wherein the refractory flux comprises a mixture of  $\text{Cr}_2\text{O}_3$ ,  $\text{SiO}_2$  and an oxide of titanium.

14. The process of claim 8, wherein said welding step is completed in a single pass orbital weld.

15. The process of claim 14, wherein a weld ring formed from a weld filler material is placed between tube ends to be welded.

16. The process of claim 15, wherein the weld ring is T-shaped in cross section so that the ring can be slipped onto a tube end.

17. The process of claim 16, wherein the flux is applied to an outer surface of the weld ring.

18. The process of claim 5, wherein the refractory flux comprises at least one of silica, titania, magnesia, chromia and TiO.

19. The process of claim 14, wherein the refractory flux comprises a mixture of  $\text{Cr}_2\text{O}_3$ ,  $\text{SiO}_2$  and an oxide of titanium.

20. The process of claim 5, wherein said welding step is completed in a single pass orbital weld.

21. The process of claim 20, wherein a weld ring formed from a weld filler material is placed between tube ends to be welded.

22. The process of claim 21, wherein the weld ring is T-shaped in cross section so that the ring can be slipped onto a tube end.

23. The process of claim 22, wherein the flux is applied to an outer surface of the weld ring.

24. An insert for welding duplex stainless steel tubing, comprising:

- a) a weld ring comprising higher % weight Ni compared to the duplex stainless steel tubing being welded; and
- b) a penetration improving flux on an outer surface of said weld ring.

25. The insert of claim 24, wherein the flux is applied to an outer surface of the weld ring after the ring is formed.

26. The insert of claim 24, wherein said flux is part of the weld ring metal matrix.

27. The insert of claim 24, wherein said filler material comprises 25.10.4.L material.

28. The insert of claim 24, wherein said flux comprises a titanium oxide.

29. An orbital welding process for joining adjacent ends of two heavy wall duplex stainless steel tubes comprising

- (a) placing a weld filler between the adjacent tube ends to be welded, the weld filler selected so that the weld bead formed by the welding process has a duplex phase structure,
- (b) applying a high refractory flux to the heat affect zone formed by the weld filler and the adjacent tube ends to be welded, and

- (c) arc welding the adjacent tube ends together in a single orbital pass using a non-pulsed arc.

30. The process of claim 29, wherein the weld filler is made from a steel containing more austenite than the duplex steel tubes being welded together.

31. The process of claim 30, wherein the filler steel contains more nickel than the duplex steel tubes being welded together.

32. The process of claim 29, wherein the flux includes a metal oxide.

33. The process of claim 29, wherein the weld filler is a weld ring having a T-shaped cross section.

34. The process of claim 29, wherein the arc is continuous.

35. An orbital welding process for joining adjacent ends of two heavy wall duplex stainless steel tubes comprising

- (a) applying a high refractory flux to the heat affect zone formed by the adjacent tube ends to be welded, and  
(b) arc welding the adjacent tube ends together in a single orbital pass using a non-pulsed arc.

36. The process of claim 29, wherein the flux includes at least one of silica, titania, magnesia, chromia and a titanium oxide.

37. The process of claim 36, wherein the refractory flux comprises a mixture of  $\text{Cr}_2\text{O}_3$ ,  $\text{SiO}_2$  and an oxide of titanium.

PCT/US 00/17414  
IPCA/US 26 SEP 2001  
ART 34 AMDT

38. The process of claim 37, wherein the refractory flux comprises a mixture of about 30 to 70 wt.% of a titanium dioxide, about 20 to 76 wt.%  $\text{Cr}_2\text{O}_3$ , and about 5 to 27 wt.%  $\text{SiO}_2$ .

39. The process of claim 38, wherein the wall thickness of the tubing being welded is greater than 2 mm.

40. The process of claim 36, wherein the wall thickness of the tubing being welded is greater than 2 mm.

41. The process of claim 35, wherein the wall thickness of the tubing being welded is greater than 2 mm.

42. The process of claim 35, wherein a weld filler made from a steel containing more austenite than the duplex steel tubes being welded together is placed between the adjacent tube ends to be welded.

43. The process of claim 42, wherein the weld filler contains more nickel than the duplex steel forming the tubes being welded together.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
1 March 2001 (01.03.2001)

PCT

(10) International Publication Number  
**WO 01/14094 A1**

(51) International Patent Classification<sup>7</sup>: **B23K 9/00**

(21) International Application Number: **PCT/US00/17414**

(22) International Filing Date: **23 June 2000 (23.06.2000)**

(25) Filing Language: **English**

(26) Publication Language: **English**

(30) Priority Data:  
60/150,738 **25 August 1999 (25.08.1999)** **US**

(71) Applicant (for all designated States except US):  
**SWAGELOK COMPANY [US/US]; 29500 Solon  
Road, Solon, OH 44139 (US).**

(72) Inventors; and

(75) Inventors/Applicants (for US only): **AMES, Nathan,  
D. [US/US]; 7910 Twin Hills Road, Streetsboro, OH  
44241 (US). MARSHALL, Andrew, P. [US/US]; 2208  
S. Bellvoir Boulevard, University Heights, OH 44188  
(US). SAPSFORD, Charles [US/US]; 104 Emmitt Road,  
Tallmadge, OH 44278 (US). WOLF, Edwin, L. [US/US];  
9977 Darrow Park Drive, Apt. 119A, Twinsburg, OH  
44087 (US).**

(74) Agents: **LEWIS, Leonard, L. et al.; Calfee, Halter &  
Grnsword LLP, 1400 McDonald Investment Center, 800 Su-  
perior Avenue, Cleveland, OH 44114 (US).**

(81) Designated States (national): **AE, AL, AM, AT, AU, AZ,  
BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK,  
DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL,  
IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU,  
LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT,  
RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA,  
UG, US, UZ, VN, YU, ZA, ZW.**

(84) Designated States (regional): **ARIPO patent (GH, GM,  
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian  
patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European  
patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE,  
IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG,  
CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).**

Published:

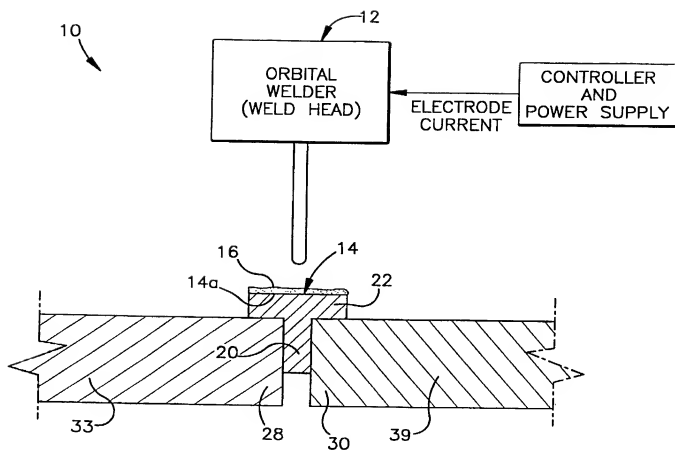
— With international search report.

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: **APPARATUS AND METHOD FOR WELDING DUPLEX STAINLESS STEEL**

(57) Abstract: Arc welding of duplex stainless steel tubing is accomplished using a non-pulsed electric arc and a high refractory weld flux. Weld beads, uniform throughout their lengths, and having a duplex phase structure and desirable profile are produced by single pass orbital welding, even if the wall thickness of the duplex tubing exceeds 2 mm.

**WO 01/14094 A1**



**DECLARATION  
AND POWER OF ATTORNEY  
ORIGINAL APPLICATION**

As below named inventors, we hereby declare that:

Our residence, post office address and citizenship are as stated below next to our names.

We believe we are the first, original and joint inventors of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**APPARATUS AND METHOD FOR WELDING DUPLEX STAINLESS STEEL**

the specification of which

☐ is attached hereto,  
☒ was filed on June 23, 2000, as PCT Appln. No. PCT/US0017414. ✓  
☐ and was amended on \_\_\_\_\_  
 (if applicable)

We hereby state that we have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

We acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

We hereby claim the benefit of foreign priority under 35 USC 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)

Priority Claimed

PCT/US00/17414 ✓  
(Number)

WO ✓  
(Country)

23 June 2000 ✓  
(Day/Month/Year)

X Yes      No

We hereby claim the benefit of United States priority under 35 USC 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims

of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of 35 USC 112, I acknowledge the duty to disclose information material to the patentability of this application as defined in 37 CFR 1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

<u>Application Serial #)</u>	<u>(Filing Date)</u>	<u>(Status)</u>
------------------------------	----------------------	-----------------

We hereby claim the benefit of United States priority under 35 USC §119(e) of any United States provisional application(s) listed below:

<u>60/150,738</u> ✓	<u>August 25, 1999</u> ✓
(Provisional Application No.)	(Filing Date)

We hereby appoint the following attorney(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Charles B. Lyon <u>Reg. No. 25,739</u>	Tara Kastelic <u>Reg. No. 35,980</u>	Jeanne E. Longmuir <u>Reg. No. 33,133</u>
Mary E. Golrick <u>Reg. No. 34,829</u>	Pamela A. Docherty <u>Reg. No. 40,591</u>	Leonard L. Lewis <u>Reg. No. 31,176</u>
John T. Wiedemann <u>Reg. No. 28,920</u>	James A. Rich <u>Reg. No. 25,519</u>	John E. Miller <u>Reg. No. 26,206</u>
June E. Rickey <u>Reg. No. 40,144</u>	Petar Kraguljac <u>Reg. No. 38,520</u>	Sean T. Moorhead <u>Reg. No. 38,564</u>
William E. Zitelli <u>Reg. No. 28,551</u>	Eileen T. Mathews <u>Reg. No. 41,973</u>	S. Paige Christopher <u>Reg. No. 39,503</u>
Nenad Pejic <u>Reg. No. 37,415</u>	George R. Hoskins <u>Reg. No. 46,780</u>	James A. Balazs <u>Reg. No. 47,401</u>
Larry W. Conner <u>Reg. No. 44,627</u>	Brian D. Johnson <u>Reg. No. 40,665</u>	Brian E. Kondas <u>Reg. No. 40,685</u>
Douglas B. McKnight <u>P-50,447</u>	Kristin J. Frost <u>P-50,627</u>	Danielle A. Somrak <u>P-50,991</u>

Address all telephone calls and correspondence to: Leonard L. Lewis, Calfee, Halter & Griswold LLP, 800 Superior Ave., Suite 1400, Cleveland, Ohio 44114-2688.



We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements and the like may jeopardize the validity of the application or any patent issued thereon.

Full name of solicitor or first inventor

Nathan D. Ames

**Inventor's  
Signature**

Date \_\_\_\_\_

**Residence &  
Post Office Address  
Citizenship**

7910 Twin Hills Road  
Streetsboro, Ohio 44241 *OH*  
USA ✓

Full name of  
second inventor

Andrew P. Marshall

Inventor's  
Signature

Date \_\_\_\_\_

Residence &  
Post Office Address  
Citizenship

2208 S. Bellvoir Boulevard  
University Heights, Ohio 44188 OH  
USA ✓

Full name of  
third inventor

**Charles Sapsford**

**Inventor's  
Signature**

Date \_\_\_\_\_

**Residence &  
Post Office Address  
Citizenship**

104 Emmitt Road  
Tallmadge, Ohio 44278 OH  
USA

We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements and the like may jeopardize the validity of the application or any patent issued thereon.

Full name of sole  
or first inventor

Nathan D. Ames

Inventor's  
Signature

\_\_\_\_\_  
Date

Residence &  
Post Office Address  
Citizenship

7910 Twin Hills Road  
Streetsboro, Ohio 44241  
USA

2-00 Full name of  
second inventor

Andrew P. Marshall

Inventor's  
Signature



1/14/02  
Date

Residence &  
Post Office Address  
Citizenship

2208 S. Bellvoir Boulevard  
University Heights, Ohio 44188 OH  
USA ✓

Full name of  
third inventor

Charles Sapsford

Inventor's  
Signature

\_\_\_\_\_  
Date

Residence &  
Post Office Address  
Citizenship

104 Emmitt Road  
Tallmadge, Ohio 44278  
USA

Full name of  
inventor

Edwin L. Wolf

Inventor's  
Signature



1-22-02  
Date

Residence &  
Post Office Address  
Citizenship ✓

9977 Darrow Park Drive, Apt. 119A  
Twinsburg, Ohio 44087  
USA

9362 FAIRMONT  
P.O. BOX 348

Novelty, OH 44072-0348 OH.